

Qualification and Selection of Flight Diode Lasers for the NuSTAR Space Mission

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The Nuclear Spectroscopic Telescope Array (NuSTAR)



NASA Small Explorer (SMEX) mission

Low-Earth equatorial orbit in 2012.

Two identical high energy (6-80 KeV) X-ray telescopes

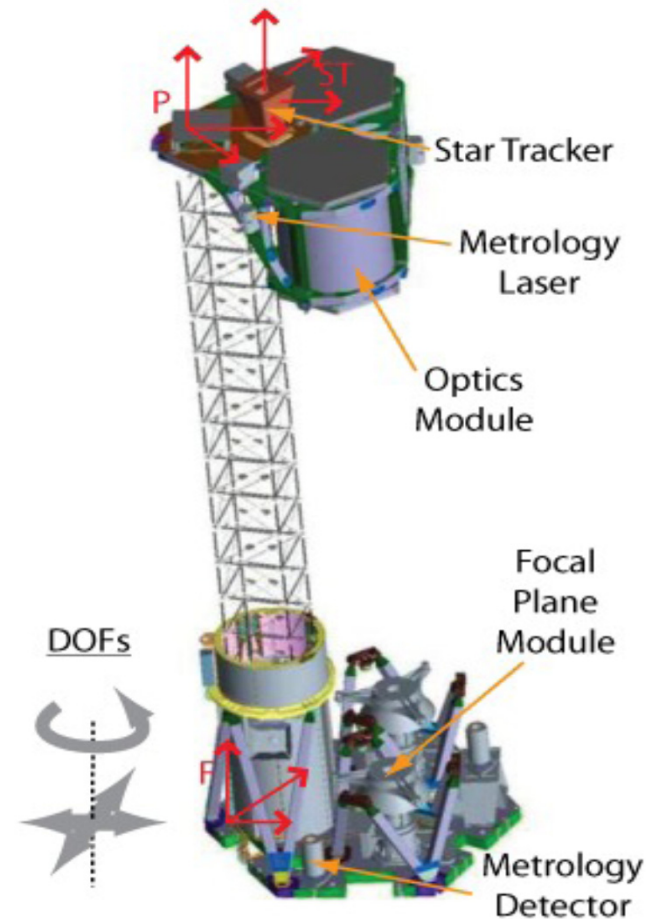
The NuSTAR mission will increase sensitivity, spatial, and spectral resolution on the order of 10 to 100 times over other missions that have operated at high X-ray energies.

The design requires a focusing length of ~10 meters

Deployable mast

A metrology system is implemented on the structure of the observatory.

The metrology system consists of two lasers mounted on the optics side of the telescopes and two position sensing detectors (PSD) mounted on the detector side of the telescopes



Overall Laser Requirements



- Sufficient signal to generate a strong signal relative to sun reflections
- Very Reliable
- Wavelength where silicon is sensitive
- Low Budget/Schedule, so have to select something already available
- Selected 830 nm, 200 mW due to heritage at JPL
- Procured 120 lasers from 2 different vendors (60 from each)
- Vendor 1: Custom Packaged (existing laser) to JPL specification. Qualified by vendor
- Vendor 2: Standard off the shelf being qualified at JPL
- Lasers are interchangeable from an optical, electrical and mechanical point of view

Detailed Laser Requirements

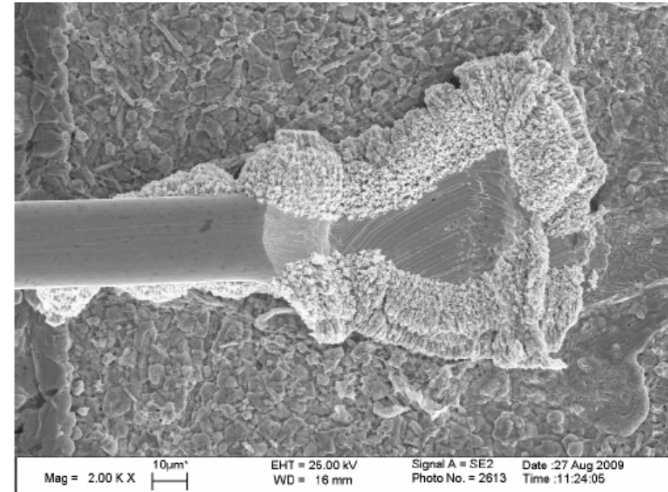


Short Title	Description
Wavelength	The center wavelength of the laser diode shall be 826.5 nm +/- 8.5 nm (no scanability is required)
Power	The optical power of the laser diode shall be ≥ 200 mW (It will only be used at 50 mW during flight)
Mode	The laser diode shall be single spatial mode
Reliability	There shall be a probability $>90\%$ that the laser diode will survive 26 months of operation when operated at 50 mW and 20 C, and on/off 4 times a second
Temperature shift	The laser diode emitting surface shall translate less than 8 nm/deg C relative to the case
Power Stability	The relative laser intensity shall not change more than $5e-5$ over a period of 20 microseconds
FIT	The laser shall have a FIT less than 11400
Beam shape	The beam should be elliptical Gaussian

Laser Failure Mechanisms



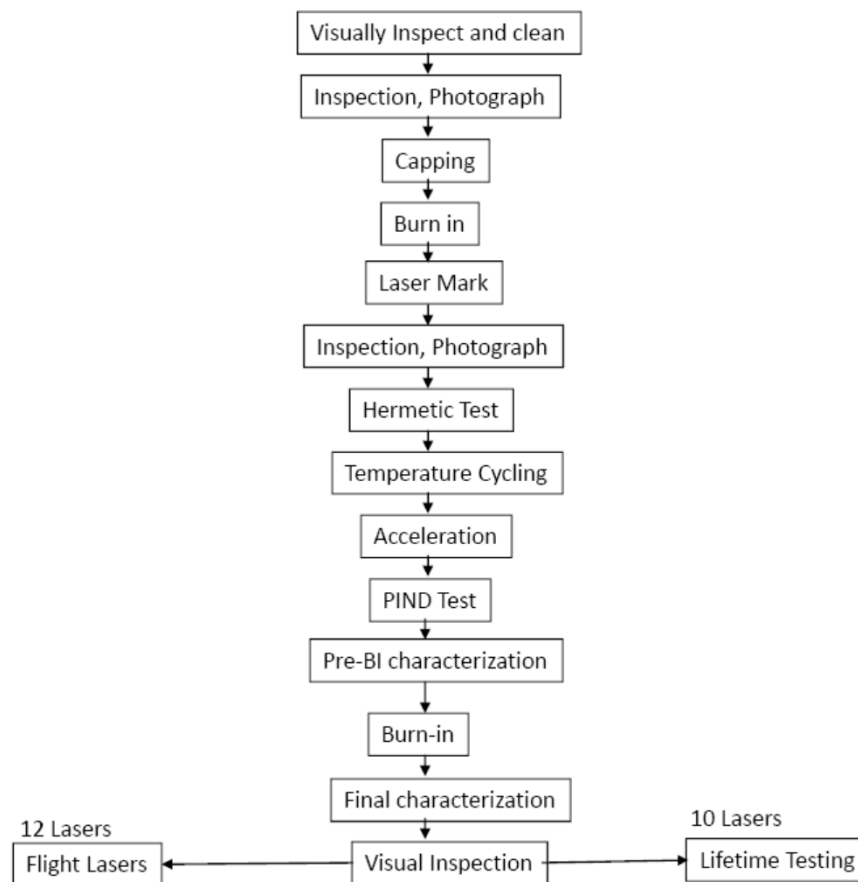
- Random failure due to optical power
- Thermo-mechanical stress of the laser chip
- Laser diodes could be electrically destroyed
- Infant mortality failures
- Solder failure/delamination of laser
- Wire bond failures
- Workmanship problems
- Solder bond line thickness
- Contamination of laser facets
- Loose particles inside the package
- Problems encountered with the use of indium (In)





Laser Vendor A Qualification Process

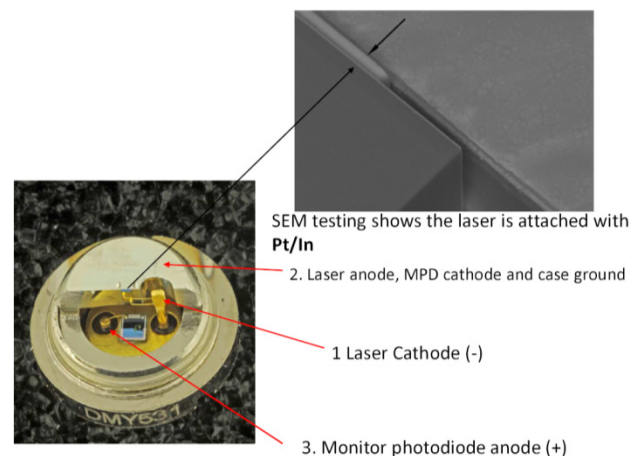
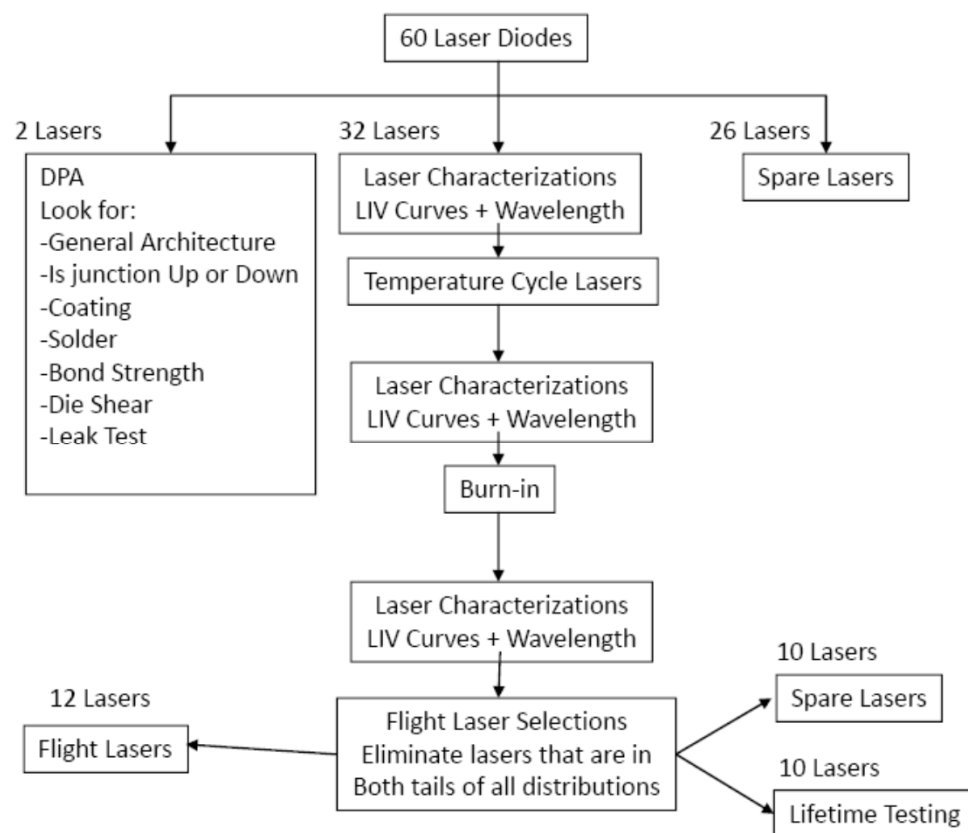
Vendor Qualification





Laser Vendor B Qualification Process

JPL Qualification of Commercial Laser



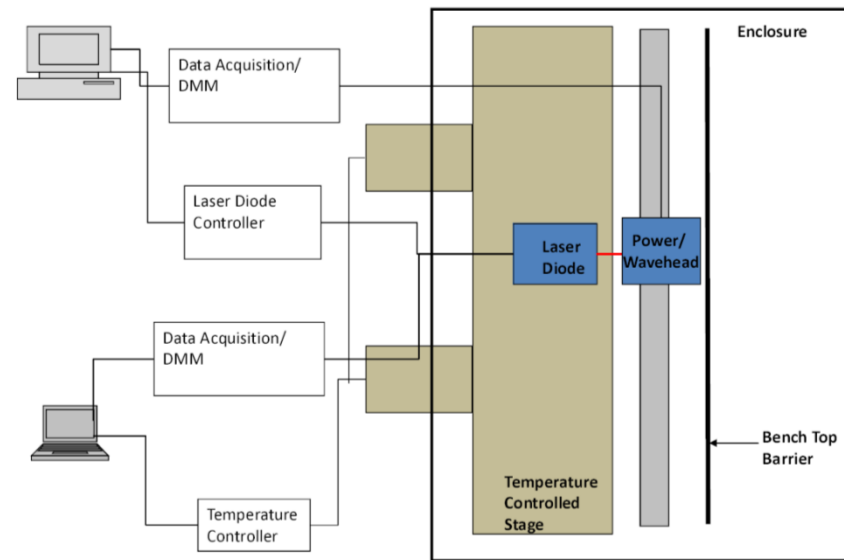
SEM image of Vendor B junction
Laser is junction down
Indium used for bonding

Laser Characterization



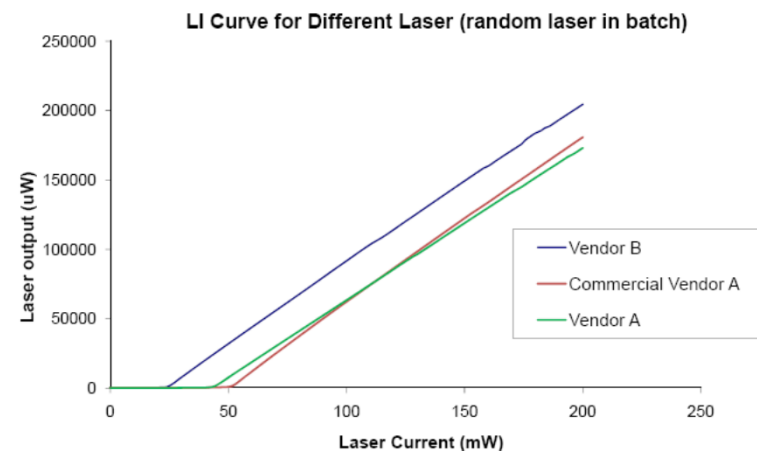
All Laser characterized for

- Voltage
- Power
- Current
- Wavelength



Characterization setup

Characterized before and after burn-in



Sample LI curve

Flight Laser Selection



All characteristics were put in histograms

- Wavelength (@ 50 mW)
- Power (@ 200 mA)
- Threshold current

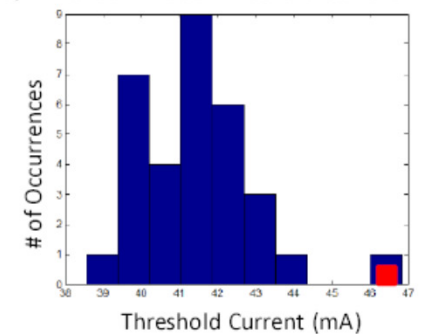
All laser with changes during burn-in were rejected

Fierce debate among authors on how to select flight lasers

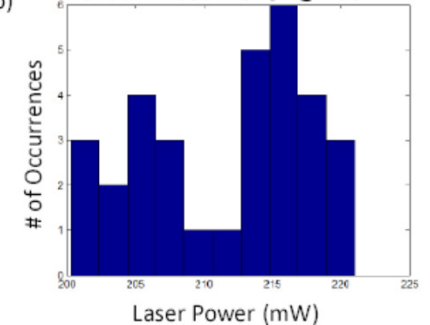
Some Authors wanted laser with best efficiency selected

Ended up with selecting average lasers (not at any extreme in any way in histograms)

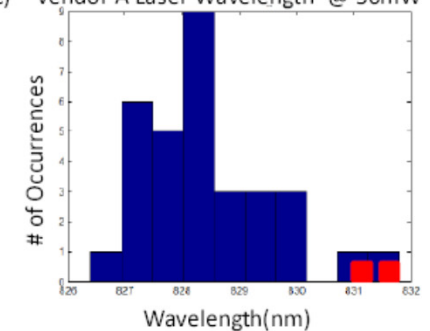
a) Vendor A Laser Threshold Current



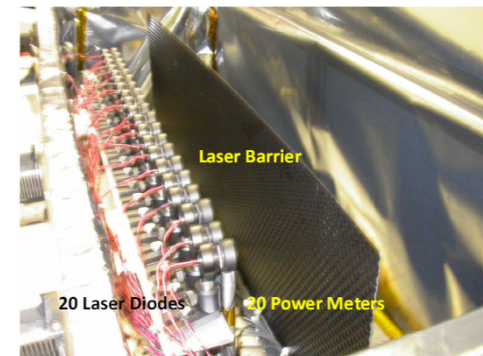
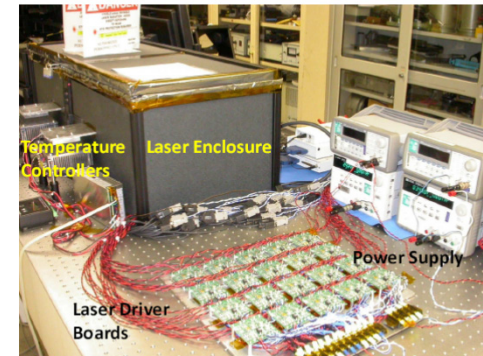
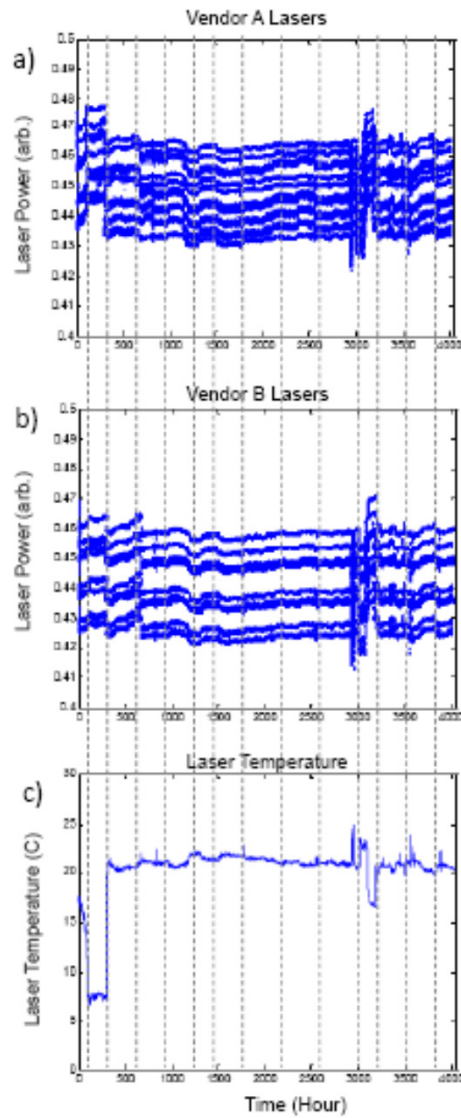
b) Vendor A Laser Power @ 200mW



c) Vendor A Laser Wavelength @ 50mW

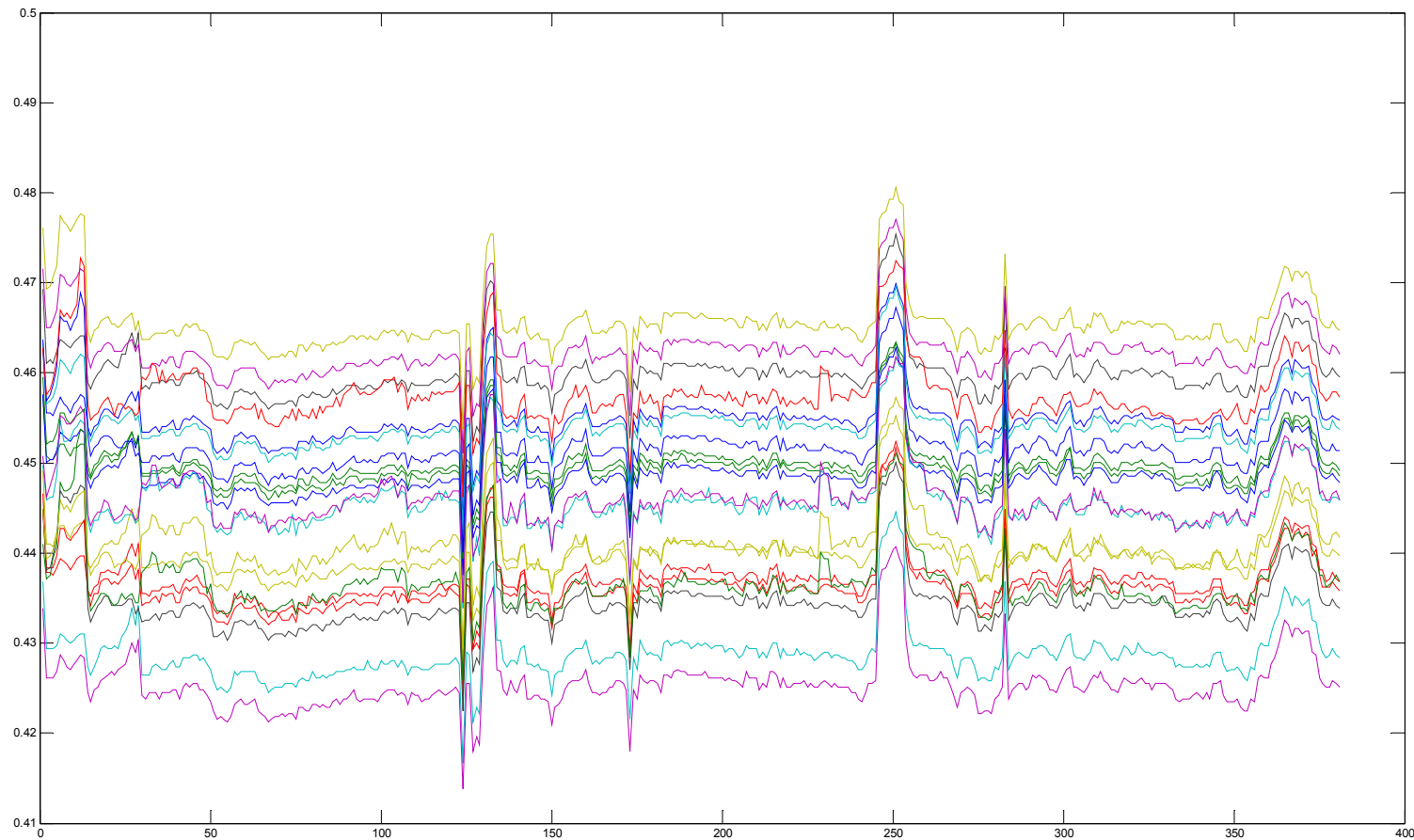


Laser Lifetime Testing



Fluctuation in power levels are due to temperature changes

Extended Laser Lifetime Testing



NuSTAR Laser lifetime testing over 381 days

The changes in the intensities are due to the temperature in the room, Air-condition failure etc. No degradation observed in any lasers.

Summary



Qualified 2 different lasers for the NuSTAR Metrology system

Extended lifetime testing showed no problems

Baseline was to fly one of each type of laser on the mission

Due to unrelated issues during the optical focusing of the system, 2 lasers from vendor A ended up on the flight instrument